# LEAD FRAME FOR AN INTEGRATED CIRCUIT CHIP
(small window)

## BACKGROUND OF THE INVENTION

This invention relates to packaging for a semiconductor device, and more particularly to a crack and delamination inhibiting lead frame for a semiconductor integrated circuit with a small window.

Conventional plastic semiconductor packages suffer from a failure mode referred to as "popcorn cracking." This failure mode occurs in packages that are exposed to ambient moisture and are then heated to high temperatures, typically during reflow soldering.

The problem apparently arises because plastic IC packages have a tendency to absorb moisture from the environment. The moisture diffuses into the encapsulant material and other materials such as the chip attach. During the solder reflow process, thermal vapor stresses developed at the chip attach/chip-pad interface or the encapsulant material/chip-pad interface cause delamination to occur, especially at areas of high interfacial stress.

A conventional full pad design is shown in figures 6, 6A and 6B where a chip or die 10 has its lower side 12 secured to a chip pad 14 by a chip attach material 16. The chip attach 16 forms a fillet 18 between the side wall 20 of the chip 10 and the upper surface 22 of the chip pad 14 in an outer region known as the shoulder 24. The pad 14 and attached chip 10 are thereafter encapsulated in an encapsulant material 26, for example epoxy forming a package 30 in a known manner. In Fig. 6A, the package 30 is fabricated on a metal leadframe 31. The package 30 includes wire bonds 37.

The failure process appears to begin with delamination or cracking of the bond between the chip and the chip-pad. This delamination may be caused by differential expansion due to the differing coefficients of thermal expansion of adjacent materials within the package. Delamination 38 of the chip 10 from the chip pad 14 can occur

when the interfacial stresses exceed the interfacial strength. Once delamination begins, it can propagate. The expanding void created by this delamination is invaded by water vapor, previously absorbed into the encapsulant material, and driven from the encapsulant by the rise in temperature. If the delamination covers a large area, the resulting long moment across which expansive water vapor forces act allows those forces to overcome the cohesive forces within the encapsulant material. In particular, delamination 38 often starts near the comer 32 of the chip 10, where the chip 10 meets the shoulder 24. In the case of the full pad design shown, delamination can rapidly propagate over the entire pad area. This can cause the package 30 to crack from the outer edge 34 of the chip pad 14 where the cohesive strength of the encapsulant material 26 is exceeded. The resulting crack may propagate through the encapsulant material 26 to the outer surface 36 of the package 30. In a like manner, delamination of the chip pad 14 from the encapsulant material 26 can also act as a crack source resulting in a popcorn failure.

These problems necessitate storage of components in humidity controlled environments prior to reflow soldering. Such required storage procedures represent additional cost and uncertainty in product quality.

<u>SUMMARY OF THE INVENTION</u>

The invention is based upon the discovery that a lead frame for a crack resistant integrated circuit package has an apertured frame, of reduced size, smaller than the integrated circuit. In a package utilizing the lead frame, the integrated circuit or chip is attached to the upper surface of the frame, and encapsulant material encloses and surrounds the frame and the chip. The encapsulant material bonds to a majority of the surface area of the chip and hardens to complete the package.

The invention provides a lead frame that reduces the initial adhesive failure, or delamination, that can occur during high temperature exposure that results in popcorn cracking. In an exemplary embodiment, this is achieved by reducing or minimizing the

size of the attachment surface of the frame to the chip. The minimal attachment surface limits the propagation of cracks and increases the available bonding surface area below the chip and encapsulant.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of the present invention will become apparent by reference to the following description and accompanying drawings wherein:

FIG. 1 is a bottom plan view of a Small-Window-Chip-Support (SWCS) lead frame according to an exemplary embodiment of the invention;

FIG. 1A is a cross section of the SWCS lead frame of FIG. 1, taken along line 1A-1A;

FIG. 2 is a plan view of a SWCS design employing grounding ring;

FIG. 2A is a cross section of the SWCS of FIG. 2, taken along line 2A-2A thereof;

FIG. 3 is a plan view of a SWCS design employing a grounding lead;

FIG. 3A is a cross section of the SWCS of FIG. 3, taken along line 3A-3A thereof;

FIG. 4 illustrates a small window arrangement with a round apertured frame;

FIG. 5 illustrates a small window arrangement with enlarged support members;

FIG. 6 is a fragmentary plan view of a conventional integrated circuit package formed on a thin metal leadframe and employing a conventional full size chip pad;

FIG. 6A is a fragmentary side elevation of the lead frame of FIG. 6; and

FIG. 6B is a fragmentary perspective view of the lead frame of FIG. 6.

DETAILED DESCRIPTION OF THE INVENTION.

FIGs.1 and 1A illustrate an exemplary embodiment of a portion of an integrated circuit package incorporating a small window chip support lead frame 42 for an integrated circuit chip or die 44 according to the invention. The chip 44 has a respective top 46, and bottom 48. It also has sides 50 and side edges 55. The lead frame 42 reduces or eliminates popcorn cracking failures during periods of high temperature processing; for example, during reflow soldering.

In the present embodiment, the lead frame 42 includes four interconnected coplanar sidebars 52 defining an aperture or window 54. In this embodiment, each sidebar 52 also has opposite ends 56 and respective inner sides 62 and outer sides 64. The outer sides 64 define a chip supporting zone 43. It is characteristic of the invention that the chip supporting zone 43 has a periphery lying generally within the periphery of the chip. In most instances, the entire lead frame 42 is etched or stamped from a thin conductive metal sheet, for example copper sheet. Typically, the thickness of the metal sheet is in the range from about 4 mils to about 8 mils. Other materials and thicknesses may be appropriate for various applications.

The sidebars 52 are joined at respective ends 56 to define the aperture 54. A chip contacting surface comprising the upper surface 63 of each side bar 52 is disposed in confronting relation with the bottom 48 of the chip 44. As shown, the chip 44 is secured to the upper surface 63 of each side bar 52 by a chip attach material 66. The

sides 50 of chip 44 are then located in spaced relation with the outer side 64 of the side bars 52 as shown.

In a known manner wire bonds 69 are connected to the top 46 of the chip 44 as schematically shown. Encapsulation material 68, shown in dotted line, is molded around the frame 42 and chip 44 as shown. The encapsulation material 68 forms a bond with the frame 42 and also bonds to the top 46, bottom 48 and sides 50 of the chip 44. As can be appreciated the encapsulating material 68 is molded through and around the frame 42 to form a firm and robust bond with the bottom 48 of the chip 44 through the aperture 54.

As noted above, the chip 44 is secured to a portion of the top surface 63 of the side bars 52 by the chip attach material, or adhesive, 66. The arrangement of chip and sidebars, discussed above, whereby the periphery of the chip supporting zone is within the periphery of the chip insures that the die attach material contacts the bottom of the chip remotely from the high-stress chip corners 41. As best shown in FIG. 1, the chip 44 is supported on the frame 42 with its sides 50 generally parallel to and spaced beyond the side bars 52, exposing available inner 98 and outer 99 bonding areas on the bottom of the chip. This allows the encapsulation material to bond to both areas on the bottom of the chip and around the frame 42 to provide a strong bond.

The upper surface 63 of each side bar 52 provides a relatively small contact area with the chip. Such a small total bonding area minimizes possibile delamination span, and the consequent probability of popcorn cracking. A window format, as compared with less integrated alternatives, is used to enhance mechanical stability during assembly prior to mold encapsulation.

As can be seen in FIG. 1 and FIG. 1A, the apertured frame 42 is surrounded by different materials including the encapsulating material 68, which thus forms materials discontinuities at various boundaries in the package 40. Accordingly, cracks originating at the interface in the chip attach material 66 between the chip 44 and the frame 42, tend to stop at the boundary where the materials are discontinuous.

Side bars 52 have a length l. Importantly, the side bar length l is at the outer side 64 generally less than the corresponding length L of the chip along the side edge 55 to thereby eliminate the chip-pad shoulder 24 and the chip-pad attach fillet 18 of the prior art.

As can be seen in FIG. 1, although the frame 42 provides a relatively small contact area for the chip 44, it is sufficient to secure the chip 44 in place while the assembly is being encapsulated. Significantly, the lead frame exhibits no shoulder region, and all die attach interfaces are remote from chip corners. Consequently the weaker materials, more prone to delamination, are not found in the high stress corner and shoulder regions. The resulting package 40 is robust, ultimately providing relatively high strength bonds between the chip and frame upon encapsulation. The permanent bond formed between the chip 44 and the encapsulation 68 has a large surface area relative to the chip attach bond. Failure of the chip attach after encapsulation thus does not adversely affect package integrity because of the superior strength of the encapsulating material.

The lead frame also includes support members 80 which extend from the corners 82 of the frame 42. The support members serve to support the sidebars 52 within the mold during application and hardening of the encapsulant material.

Various other embodiments of the invention provide advantages complimentary to those already described.

FIGs. 2 and 2A illustrate a ground ring 81 which surrounds the chip 44 and is in spaced relation therewith. As shown, the ground ring 81 is electrically conductive and forms a ground plane for the chip 44.

FIGs. 3 and 3A illustrates an arrangement with a ground lead 86 having a proximal of end 88 connected to the frame 42 and having a free end 90 for ground wire bonding if needed.

FIG. 4 illustrates a small window arrangement with a round apertured frame. In this embodiment, the function of the sidebars 52, as illustrated in FIG. 1 is performed

by a circular or annular member 100 with a circumferential edge 101 and upper surface 102 fixed in bearing contact with the bottom 104 of the chip 106, and disposed within the chip edge 108.

FIG. 5 illustrates a small window arrangement with enlarged support members 120.

This arrangement presents additional surface area to the bottom of the chip 122, and provides additional stability during the molding of encapsulant material, and possibly thermal benefits in operation.

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~~FIG. 5 further illustrates an aperture traversing member 125. In this embodiment, this member serves to divide the aperture into two smaller apertures 126 and 127.~~

It will be appreciated by persons skilled in the art that numerous variations and modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are therefore to be considered in all respects illustrative and not restrictive.